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ANALYSIS OF SKY-WAVE FIELD INTENSITY—PART I

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ABSTRACT. The paper presents a statistical analysis of field intensity of the internal short wave stations of All India Radio over the period of a complete solar cycle (1942-52). The yearly, seasonal and monthly variations of the field intensity and their correlation with sunspot numbers have been shown in a series of graphs. An interesting feature of the analysis is that the night-time field intensity has been found to be correlated with solar activity. This is rather inexplicable since no ionospheric absorption is usually assumed for the night-time propagation.

I. INTRODUCTION

It is known that over long distances of propagation, short wave radio communication is carried out *via* the ionosphere and is, therefore, influenced by the variable conditions occurring therein. It is generally observed that short wave radio signal varies in its intensity both on a short term as well as on a long term basis. At present, it is rather difficult to explain the exact nature and cause of such variations, mainly due to our inadequate knowledge of the ionosphere and its effect on short wave radio communication. However, an indirect attempt to study the nature of such varying conditions can be made by correlating the field iintensity observations with known variable parameters as are associated with the characteristics of the ionosphere.

This paper presents the results of some statistical studies of the observed values of field intensity of the internal short wave stations of All India Radio over a period of a complete solar cycle(1942-1952). The measurements of field intensity of Bombay, Calcutta and Madras transmitters are made at regular intervals at Delhi. The stations use frequencies in the 3, 4, 5, 6, 7 and 9 Mc/s bands for their internal services. Sufficient data are available for the various frequencies at different times of the day and night. The analysis has been carried out with a view to studying the monthly, seasonal and sunspot cycle variation of field intensity.

In Part II of the paper, a comparison will be made between the observed values of the field strength and those calculated from known methods. The various assumptions in the methods of calculation will also be discussed.

2. METHOD OF ANALYSIS

Measurements of field intensity made by All India Radio at Delhi on frequencies in the 3, 5, 7 and 9 Mc/s bands from each of the three transmitting stations at Bombay, Calcutta and Madras at different times of the day and night, have been used for the analysis. In order to find out how the ionospheric absorption influences propagation of these frequencies, two representative times have been considered. The periods are (*a*) between 1200 and 1400 hours IST which is considered to correspond to the period of maximum absorption and (b) between 2000 and 2200 hours IST, which corresponds to the minimum absorption. IST (Indian Standard Time) is 5½ hours ahead of GMT. In order to find out the monthly value of the field intensity, all the measurements between 1200 and 1400 IST on any frequency for any of the three stations for a particular month are grouped together and the average value is called the *midday* field intensity for the month. Similarly, the average value between 2000 and 2200 IST is calculated and is called the *night-time* field intensity.

It has been found that there is not much difference in the value of field intensity on a particular frequency at 1200 from its value at 1400 IST on a particular day and similarly the field intensity at 2000 is very nearly the same as at 2200 IST. The day-to-day variation in the field strength on any of the frequencies at any hour between 1200 and 1400 IST is not large, while the same between 2000 and 2200 IST is sometimes appreciable. It has, however, been observed that the ratio between the maximum and the minimum for the period 2000 to 2200 IST hardly exceeds 3 to 4 db. During the period 1200-1400 IST, the ratio is much less.

The monthly mean values of field intensity are thus arrived at for the midday and night-time periods on 3,5,7 and 9 Mc/s bands for the transmitters at Bombay, Calcutta and Madras for the period 1942-1952. These monthly mean values represent the 'Upper Decile' figures of the field intensity. For convenience of analysis, the upper decile values have been reduced by 13.3 db to arrive at the corresponding lower decile figures. It may be pointed out that in practical problems on radio transmissions, the lower decile value is usually of greater interest than the upper decile figure. Thus, all field intensity values shown in the paper in the form of curves etc., represent the lower decile figures.

The measurements of field intensity of the internal short wave stations of All India Radio at Bombay, Calcutta and Madras which are analysed in this paper were carried out at Delhi. The distance of the receiving centre from the transmitting stations and their location are given below:—

(i) Bombay (Lat. 19° 0′N, Long: 73° 0′E), distance from receiving station: 1140 kms.

(ii) Calcutta (Lat. 22° 30′N, Long: 88° 30′ E), distance from receiving station: 1320 kms.

(iii) Madras (Lat: 13° 0′ N, Long: 80° 15′ E), distance from receiving station: 1760 kms. Receiving station: Delhi (Lat: 28° 35′N, Long: 77° 5′E)

The transmitters at all the different stations are indentical and radiate a power of 10 kw. The transmitting aerial is mostly a horizontal dipole situated $7/16\lambda$ above the ground.

The following analyses have been carried out:

(i) Correlation with sunspot number.

(ii) Monthly variation of field intensity.

(iii) Yearly variation of field intensity for different seasons.

The results of the analysis are presented graphically wherein the values shown for the field intensity are in decibels above one microvolt per metre.

3. (i). CORRELATION WITH SUNSPOT NUMBER

To study the effect of the sunspot number on the variation of field intensity, yearly averages of all the mean values for the midday and night-time periods, and the relative sunspot number for the years have been plotted. This analysis is particularly interesting for the night-time period since theoretically it is assumed that during the night the ionospheric absorption is usually negligible and for all practical purposes of calculations, it is taken to be zero. A correlation with sunspot activity would indicate that the inonospheric absorption cannot be neglected during the night and a proper allowance should be made. This will further be discussed later in the paper.

3 (ii). MONTHLY VARIATION OF THE FIELD INTENSITY

An analysis has been made to indicate the variation of field intensity from month to month over the period 1942-1952. The mean values of field intensities for a particular month over the 11 year period have been grouped together and averages arrived at. The average field intensity for different months is plotted for different frequencies and transmitting stations. The resulting curve would, therefore, indicate the average variation in the field intensity that would be expected from month to month during a complete solar cycle. A better method of representing this monthly variation would have been to plot separate system of curves for each sunspot index, e.g., maximum, medium and minimum and indicate the average monthly variation during different phases of sunspot activity. Such a system would have been of more practical interest since one would be able to compute from these curves the changes in the monthly values of field intensity associated with solar activity. We have not included such analysis in the present paper since sufficient measurements of field intensity in different months are not available for any frequency for any of the transmitting stations for different phases of solar activity.

3 (iii). YEARLY VARIATION OF FIELD INTENSITY

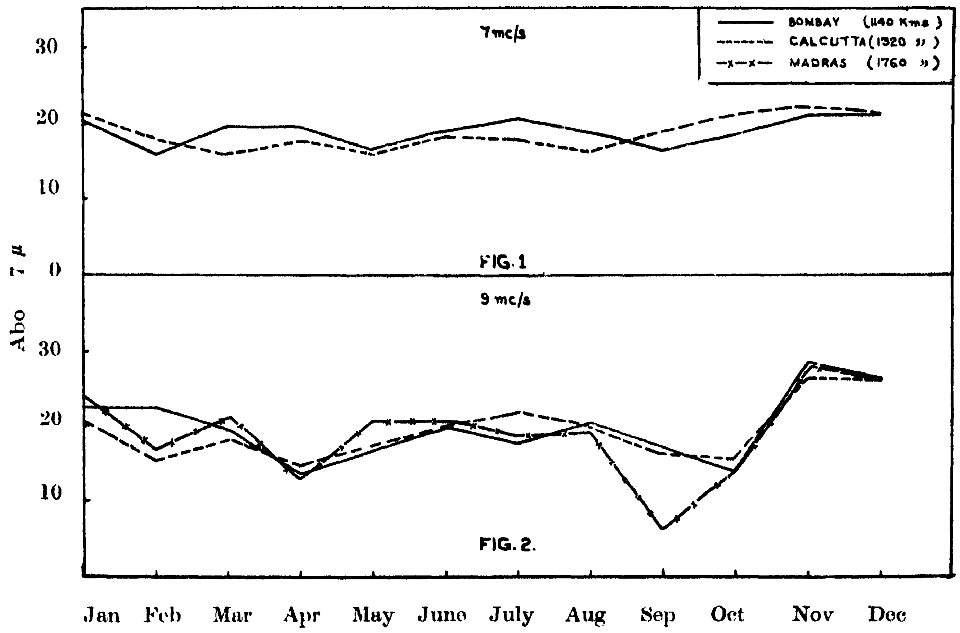
In order to study the yearly variation of field intensity in different seasons and its correlation with sunspot number, the monthly mean values have been grouped together for the three seasons namely, summer (May to August), winter (November to February) and equinox (March, April, September and October). The average field intensity for any season has, then been plotted for different years. The yearly average sunspot number is also indicated in the same figure to show correlation of field intensity with solar activity. Separate curves have been plotted for separate frequencies and for different transmitting stations.

4. RESULTS OF THE ANALYSIS

The three types of analysis described above have been made for all operating frequencies of the stations (Bombay, Calcutta and Madras), in the 3, 5, 7 and 9 Mc/s bands during midday and night-time periods. The results of the analysis are discussed below for midday and night-time periods separately.

(*a*) *Midday Period* (1200-1400 IST)

7 and 9 Mc/s have mostly been used at Bombay, Calcutta and Madras for the period 1942-1952. No attempt has been made to correlate the yearly variation of field intensity with sunspot number, since sufficient data are not available in



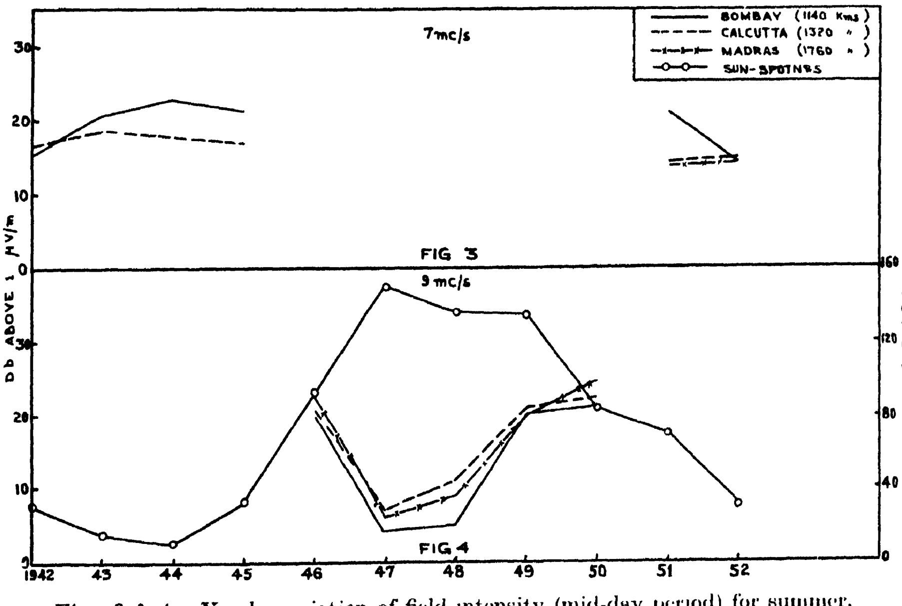
Figs. 1 & 2. Monthly variation of field intensity (mid-day period).

each year on either 7 or 9 Mc/s. This is because partly 7 and partly 9 Mc/s was used during the midday period over the 11 years.

The monthly variation of the field intensity (Sec. 3-ii) has been shown in figures 1 and 2 for 7 and 9 Mc/s respectively. It will be seen from figure 1 that on 7 Mc/s there is not much variation in the field intensity from month to month. The maximum to minimum variation for Bombay is from 21 to 16 db above 1 μv/m, the average being about 18 db. For Calcutta, the maximum to minimum variation is roughly the same and the average is somewhat lower than that of Bombay. For Madras, mearurements for sufficient number of years are not available for an analysis to be made. So far as the seasonal variation is concerned, it is interesting to note that there is no appreciable difference in the field intensity from summer to winter.

9 Mc/s has been more extensively used in the midday period. Figure 2 shows that the monthly variations of the field intensity for Bombay, Calcutta and Madras are not much different from one another. Higher values have been obtained in November and December as expected. The average value for most of the months is about 18 db above 1μv/m.

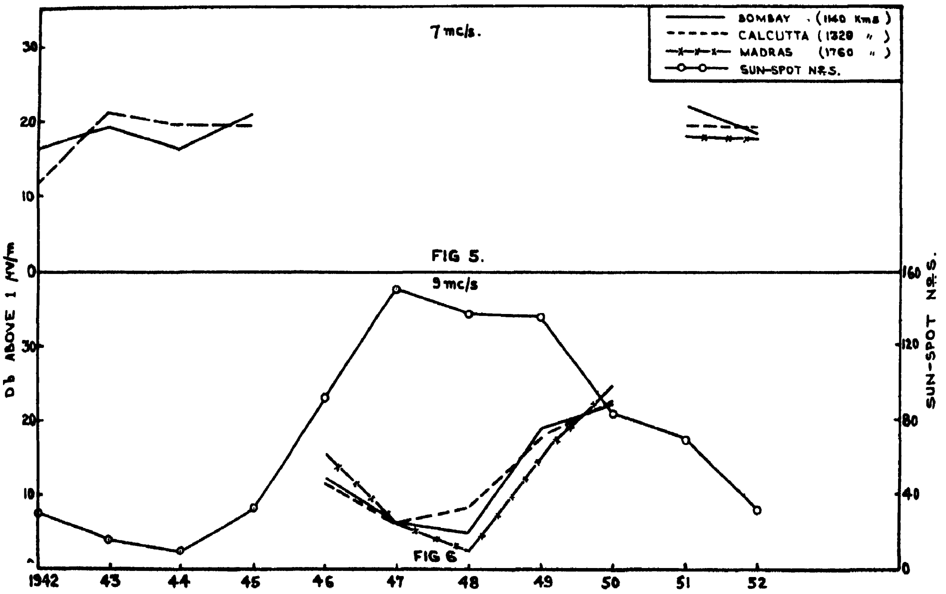
Figures 3 and 4 show the yearly variation of the field intensity (see Section 3-iii) on 7 and 9 Mc/s for summer. The sunspot number has also been shown for correlation. It will be seen from these figures that 7 Mc/s has been used in low sunspot period and 9 Mc/s in high sunspot activity. The variations of field



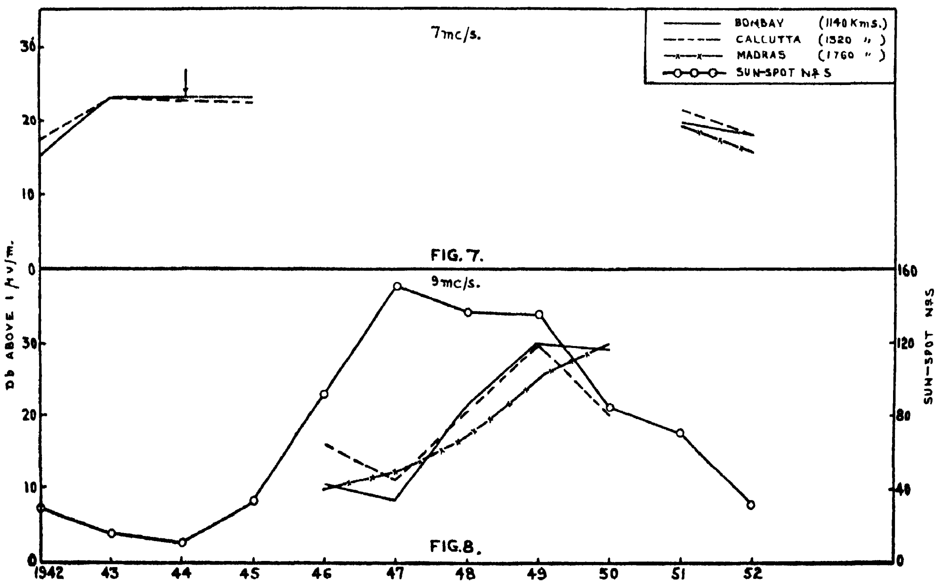
Figs. 3 & 4. Yearly variation of field intensity (mid-day period) for summer.

intensity are well correlated with the sunspot activity: the field intensity is low on high sunspot activity and vice versa. This is expected since the ionospheric absorption (non-deviative) is supposed to have a linear relationship with sunspot number.

Figures 5 to 8 show similar variation of field intensity for equinox and winter. While in equinox there is a close correlation with sunspot activity, in winter it will be seen that for Calcutta and Bombay, the field intensity is lower in low



Figs. 5 & 6. Yearly variation of field intensity (mid-day period) for equinox).



Figs. 7 & 8. Yearly variation of field intensity (mid-day period) for winter. ↓ indicates interpolated values.

sunspot activity period. It is too early to suggest any reason for this apparent discrepancy; more data are required.

(*b*) *Night-Time Period* (2000-2200 *IST*).

3 and 5 Mc/s have mostly been used at Bombay, Calcutta and Madras for the period 1942-1952. Figure 9 shows the correlation with sunspot activity (Sec. 3-i) of the yearly average of the field intensity on 5 Mc/s for the transmitters at Bombay, Calcutta and Madras. It will be noted that the yearly variation of field intensity is more or less well correlated with sunspot numbers, although for Madras, the correlation is not so well defined. The analysis indicates that it is not correct to assume specular reflection from the ionosphere during night with zero

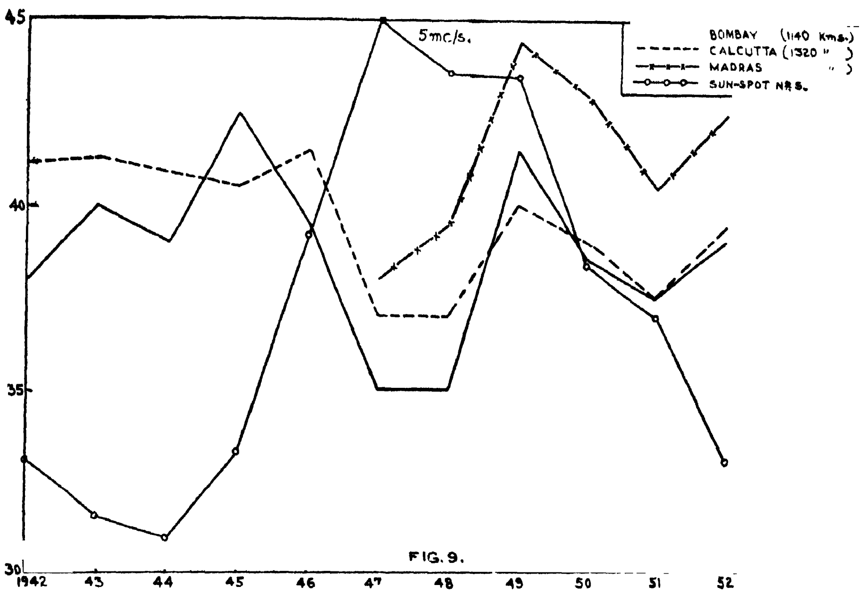
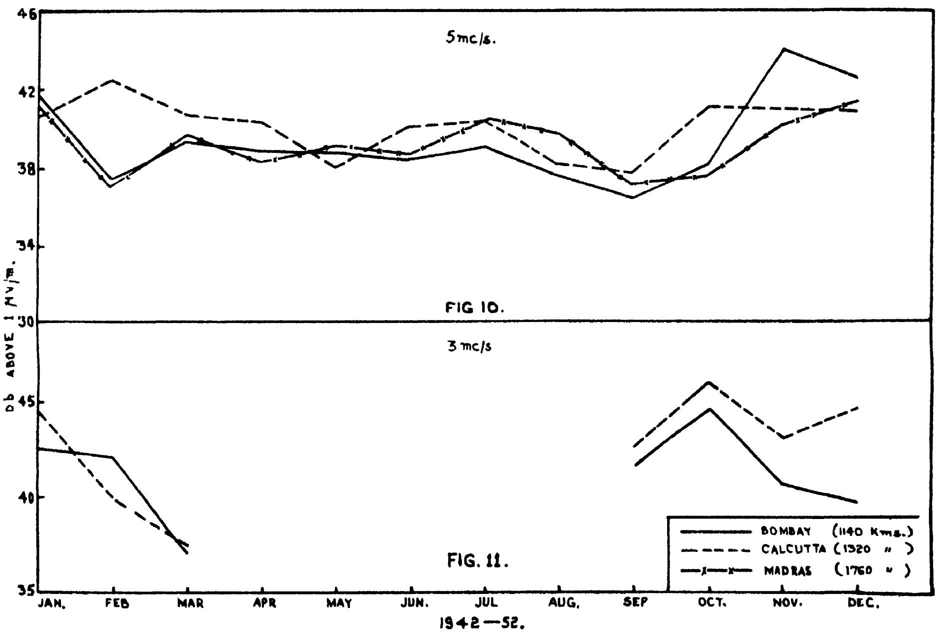


Fig. 9. Correlation with sunspot activity (night-time).

absorption. The sunspot cycle has a distinct effect on ionospheric propagation during the night; the exact mechanism of its effect on the absorption at night is, however, not clearly understood. But it is apparent that due allowance should be made for the sunspot cycle when theoretical calculation of field intensity on long distance propagation during night is undertaken. No attempt is made to evolve an empirical formula for such absorption since the data at our disposal are not considered sufficient.

Figures 10 and 11 show the monthly variation of field strength (Sec. 3-ii) on 5 and 3 Mc/s respectively. 3 Mc/s has not been used for the months April to August, the frequency being well below the optimum frequency of operation. The Madras transmitter has also used 3 Mc/s very infrequently and the monthly variation of its field intensity has, therefore, not been shown in figure 11.

It will be seen from figure 10 that the monthly variation of field intensity in respect of the transmitters at Bombay, Calcutta and Madras follow one another during most of the months. There are, however, significant variations during the winter months. Calcutta figures are higher than the corresponding ones for Bombay and Madras during the months of January and February. Similarly, the Bombay figures are higher in the months of November and December than the corresponding ones for Calcutta and Madras. These variations can to some extent be explained to be due to the different distances of transmissions involved



Figs. 10 & 11. Monthly variation of field intensity (night-time).

and the difference in the orientation of the aerials at the three transmitting stations with respect to the receiving station at Delhi. The downward monthly trend for Bombay and Madras figures for the months of January and February is inexplicable since one would except the field intensity to be higher during the winter month. Calcutta figures, however, show an upward trend. It was earlier seen in figure 1, that on 7 Mc/s during midday there was no significant difference between the field intensities from month to month. In figure 10, it is seen that although the field intensities for the three stations during the period March to October do not vary much, the average being of the order of 40 db, the variations for the winter months are quite significant. Insufficient data are available re-regarding field intensity on 3 Mc/s (figure 11).

Figure 12 shows the yearly variation of the field intensity (Sec. 3-iii) on 5 Mc/s for summer. The sunspot number has also been shown for correlation. It will be seen from this figure that there is some correlation between the field intensity and solar activity. The field intensity is quite low during high sunspot activity and high during low sunspot numbers. There is also a close correlation between the field intensity variations for Bombay, Calcutta and Madras from year to year. The trend is nearly the same for all the three stations.

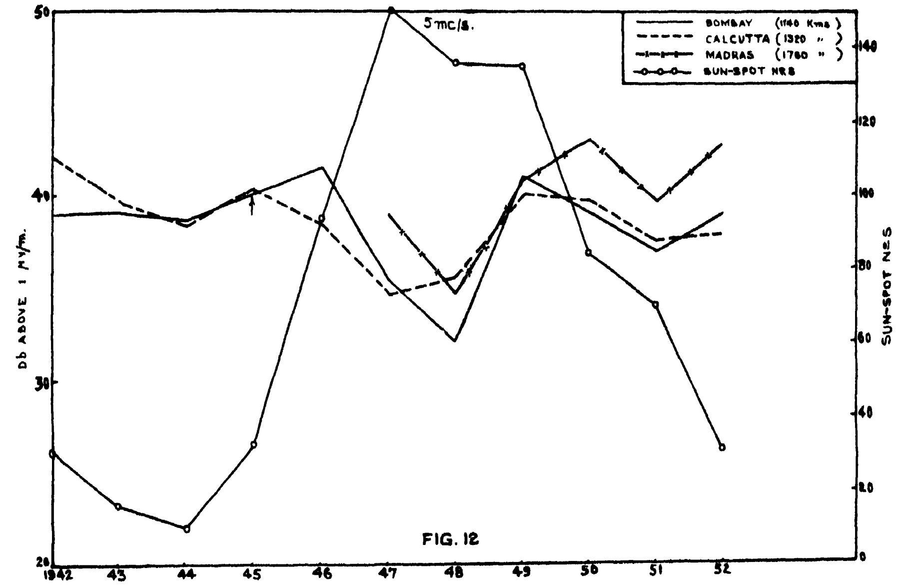


Fig. 12. Yearly variation of field intensity (night-time) for summer. ↓ indicates interpolated values.

Figure 13 shows the yearly variation of the field intensity on 5 Mc/s for equinox. While there is some correlation between the field intensity and sunspot activity in summer for all the stations (figure 12), it will be seen from figure 13 that the variation of field intensity for Madras shows an inverse correlation with sunspot numbers in equinox during the year 1942-45. So far as Bombay and Calcutta are concerned, they do show some correlation. The peculiar behaviour for Madras is not readily understandable.

Figure 14 shows the yearly variation of the field intensity on 5 Mc/s for winter. Here again the Madras field intensity shows an inverse correlation with sunspot numbers (1946-49) as in the case of equinox. It is significant to note that the field intensity variations for Madras indicate inverse correlationship with sunspot activity both for equinox and winter seasons, whereas in summer the position is as one would expect.

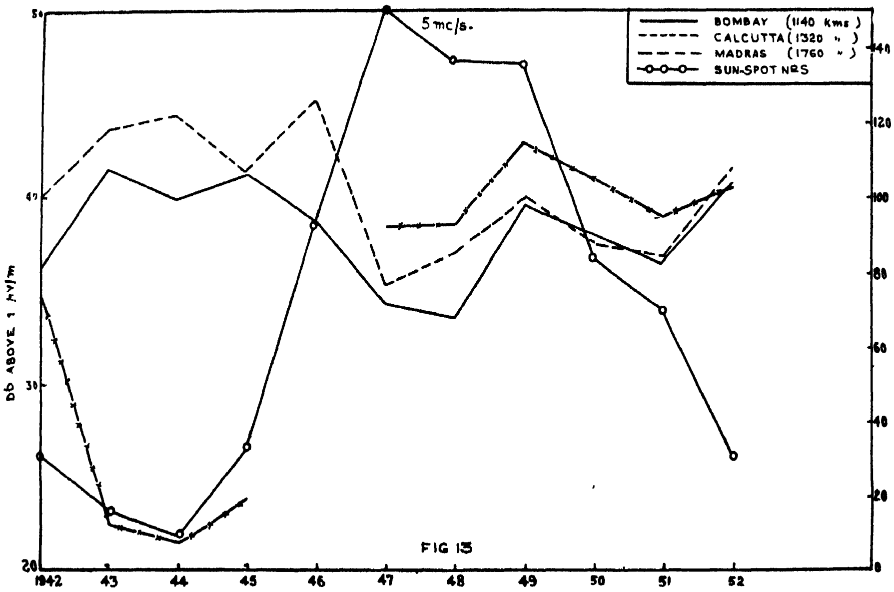


Fig. 13. Yearly variation of field intensity (night-time) for equinox.

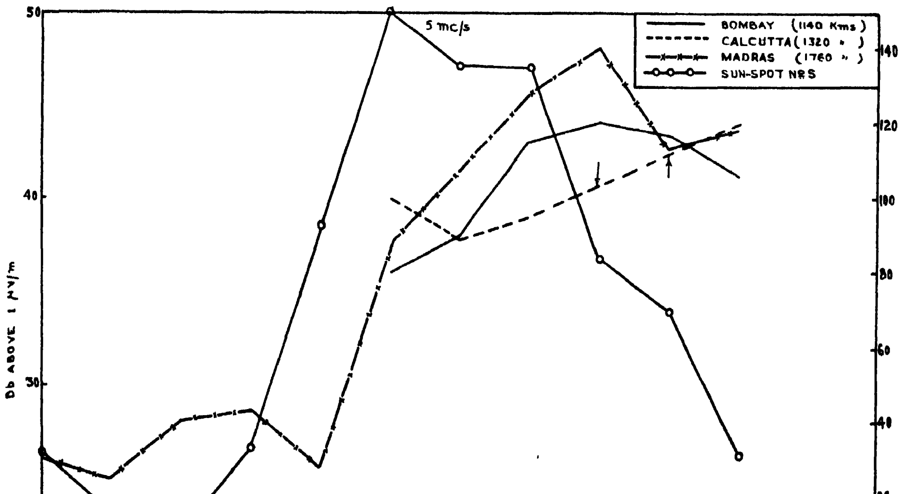


Fig. 14. Yearly variation of field intensity (night-time) for winter. ↓ indicates interpolated values.

As already indicated, sufficient measurements are not available on 3 Mc/s. This band has mostly been used in winter and the yearly variations for Bombay

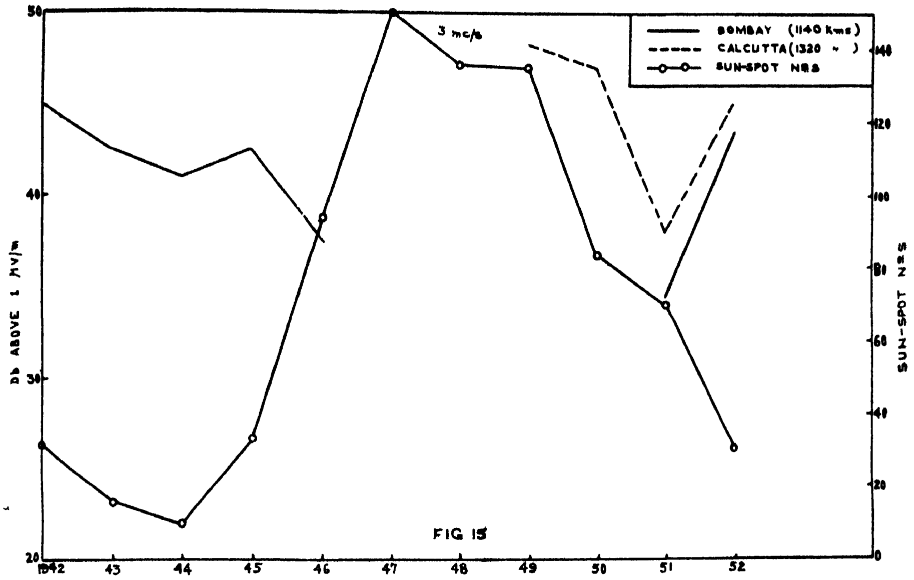


Fig. 15. Yearly variation of field intensity (night-time) for winter.)

and Calcutta are shown in figure 15. Even with the limited data, it is seen that the field intensity variations show some correlation with sunspot activity.

5. SUMMARY AND CONCLUSION

We note from figures 1 to 8 that both the monthly and yearly variations of the field intensity for different seasons during midday as observed at Delhi for transmitters at Bombay, Calcutta and Madras radiating on 9 Mc/s follow the sunspot activity rather closely. The values calculated from the CRPL and the SPIM (1952) methods are somewhat higher which we shall discuss in Part II of this paper.

Figure 9 indicates correlation of night-time field intensity with sunspot numbers. Figure 10 to 15 indicate monthly and yearly variations of the field intensity for different seasons during the night-time period as observed at Delhi for transmitters at Bombay, Calcutta and Madras radiating on 3 and 5 Mc/s. The interesting feature of this analysis is that there appears to be a close correlation with sunspot numbers even during the night-time. Absorption seems to be higher on high sunspot activity and lower on the low values of sunspot numbers. This indicates a possibility that there is a residual D- and E-layer ionisation during the night-time on higher sunspot numbers. The recombination rate may also be insufficient to eliminate at night all the D- and E-layer ionisation as produced during the day-time. This may be due to a higher ion-density during the day for which the collisional frequency is not sufficient as to produce a complete recombination during the night.

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